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SPATIAL DISTRIBUTION OF SELECTED SOIL FEATURES IN HAJDÚ-BIHAR COUNTY REPRESENTED BY DIGITAL SOIL MAPS

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Abstract
With the ongoing DOSoReMI.hu project we aimed to significantly extend the potential, how soil information requirements could be satisfied in Hungary. We started to compile digital soil maps, which fulfil optimally general as well as specific national and international demands from the aspect of thematic, spatial and temporal accuracy. In addition to relevant and available auxiliary, spatial data themes related to soil forming factors and/or to indicative environmental elements we heavily lean on the various national soil databases. The set of the applied digital soil mapping techniques is gradually broadened. In our paper we present some results in the form of brand new soil maps focusing on the territory of Hajdú-Bihar county.

Keywords: digital soil mapping, soil property map, functional soil map, soil related map, soil spatial data infrastructure, soil type map

1. Introduction

Grace to former soil surveys and mapping activities significant amount of soil information has accumulated in Hungary (Várallyay 2012). Present soil data requirements (delineation of areas with natural constraints or areas with excellent productivity; support of irrigation strategies; flood, drought and climate change impact risk assessment etc.) increasingly demand advanced or new kinds of spatial soil information, which cannot be fully satisfied by legacy soil maps or formerly elaborated databases. Due to the more and more frequently emerging discrepancies between the available and the expected data, there might be notable imperfection as for the accuracy and reliability of the delivered products.

Since the opportunity of a recent, extended, nationwide mapping is extremely low, the data of previous surveys should be exploited thoroughly for the elaboration of target specific, goal oriented spatial soil information applying up-to-date methods of soil mapping. Digital soil mapping (McBratney et al. 2003; Lagacherie et al. 2007; Hartemink et al. 2008; Boettinger et al. 2010; Minasny et al. 2012) integrates GIS, geostatistical and data mining (machine learning) tools and makes possible the elaboration of soil maps with improved and/or specific thematic, spatial and temporal accuracy as opposed to former, more general soil maps.

The DOSoReMI.hu (Digital, Optimized, Soil Related Maps and Information in Hungary) project was started intentionally for the renewal of the national soil spatial infrastructure in Hungary (Pásztor et al. 2014, 2015). During our activities we have significantly extended the potential, how soil information requirements could be satisfied. Soil property, soil type as well as functional soil maps were targeted. The maps were further processed, since even DOSoReMI.hu intended to take steps for the regionalization of higher level soil information (processes, functions, services), including for example crop models in the spatial modelling. In our paper the results are presented in the form of brand new soil (related) maps, to show and emphasize the differences between the representation of the soil cover on the traditional, widespread and the newly created soil maps, respectively. The maps were originally compiled on countrywide level, however, their spatial resolution (characteristically 1 ha) makes them appropriate also for regional utilization.

2. Soil type map according to the Hungarian traditional genetic soil classification system

Traditionally in Hungary the soil cover under agricultural and forestry management is typically characterized independently and just approximately identically. Soil data collection is carried out and the databases of soil features are managed irrespectively. As a consequence, nationwide soil maps cannot be considered homogeneously predictive for soils of croplands and forests, planes and hilly/mountainous regions. In order to compile a national soil type map with harmonized legend as well as with spatially relatively homogeneous predictive power and accuracy, resources from agricultural and forestry origin were unified. Soil profile data originating from the two sources were cleaned and harmonized according to the traditional Hungarian soil classification system (Stefanovits 1972, 1963; Szabolcs 1966; Várallyay et al. 1979). Various methods were tested for the compilation of the target map: segmentation of a synthesized image consisting of the predictor variables, multi stage classification by Classification and Regression Trees, Random Forests and Artificial Neural Networks. With a combination of best performing classifiers, when each classifier's vote on the same object is weighted according to its confidence in the voted class, led to the final product: a unified, national, soil type map with spatially

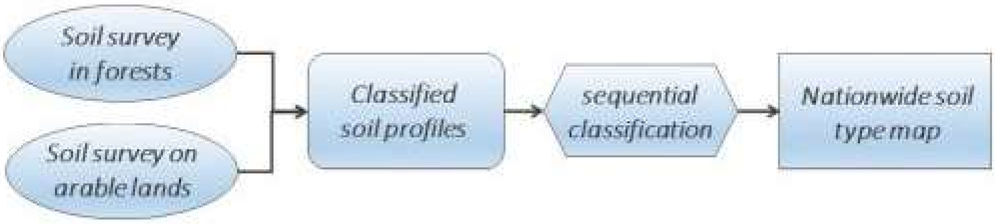

Fig. 1. Compilation procedure of the nationwide genetic soil type map

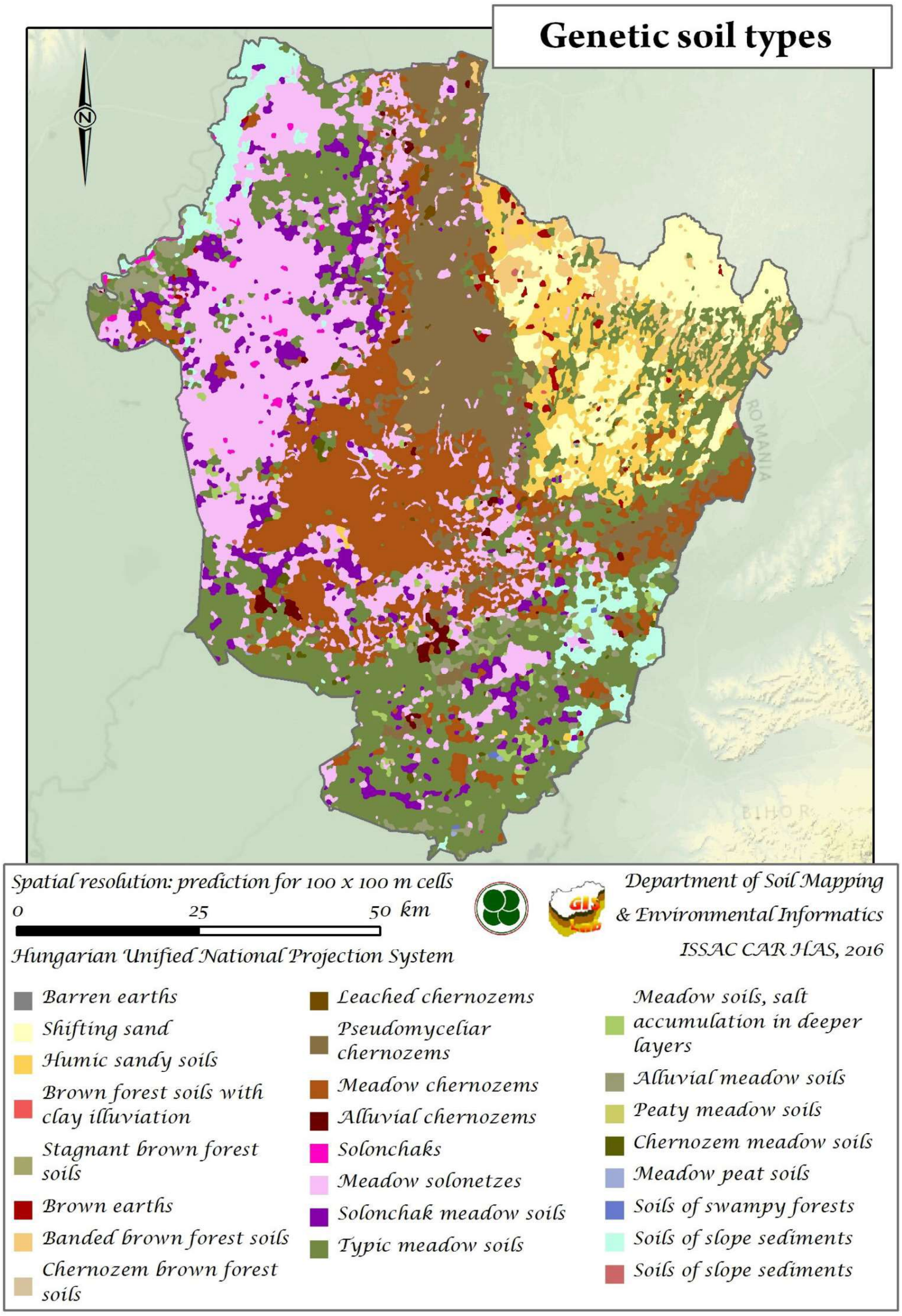

Fig. 2. Soil type map according to the Hungarian traditional genetic soil classification system

consistent predictive capabilities. The nationwide map creation workflow (Fig. 1) is presented in details in recent papers (Illés et al. 2016; Pásztor et al. 2016a). The map itself will be published in a properly generalized form in the new National Atlas of Hungary. For the support of regional studies, the countrywide map was clipped and compiled as layout for the area of Hajdú-Bihar county (Fig. 2).

3. Soil texture maps by standard layers according to the USDA classification system

Spatial information about physical soil properties is intensely expected, being basic input data in numerous applications. Soil texture can be characterized by different approaches like particle size distribution, plasticity index or soil texture classification. In accordance with the increasing demands on spatial soil texture information, our aim was to compile soil texture class maps for various soil layers according to the USDA categorization with proper spatial resolution. Regression kriging was applied, which is widely used in Digital Soil Mapping, and has numerous advantages. Primarily, reference soil data was provided by the Hungarian Soil Information and Monitoring System (SIMS 1995). Digital elevation model (EU-DEM 2015) and its derived components, geological (Gyalog – Síkhegyi 2005; Bakacsi et al. 2014) and land cover (CLC50, Büttner et al. 2004) map, appropriate remote sensing products (MODIS RED, NIR, NDVI: NASA 2015) together with the soil map featuring overall physical properties provided by the Digital Kreybig Soil Information System (Pásztor et al. 2012) have been applied as auxiliary environmental co-variables. The result maps can be widely utilized as direct input in meteorological and hydrological modelling as well as in spatial planning.

The particle-size data were classified according to the USDA (1987) texture categories, which represented the predicted variable in the mapping process. Soil textural classes are defined by the weight percentage of sand, silt, and clay in the fine-earth fraction (≤ 2 mm). The divisions can be depicted on a triangle diagram, the so-called 'texture triangle'. If the percentage of any two of the soil separates is known, the correct textural class is determined; simultaneously, the sum of the three percentages must total 100 percent. SIMS is the most unified and thematically detailed, up-to-date soil-related database in Hungary with recently collected data, providing soil information for more than 1200 locations. It contains particle size distribution data, which were converted into clay, silt and sand particle size fractions according to the USDA size-groups of mineral particles. In SIMS the soil layer related data refer to different depth intervals. For standardization we transformed the soil particle-size fraction values of each soil profile into standard depth intervals (0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, 60-100 cm, 100-200 cm; according to the internationally most accepted and spread GlobalSoilMap

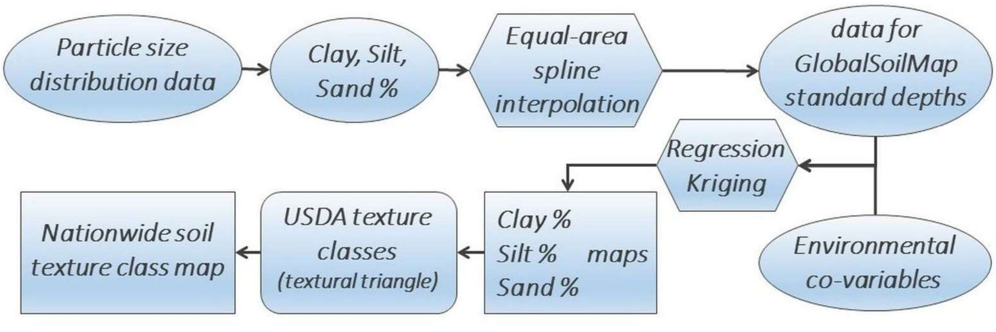

Fig. 3. Workflow of mapping soil texture classes

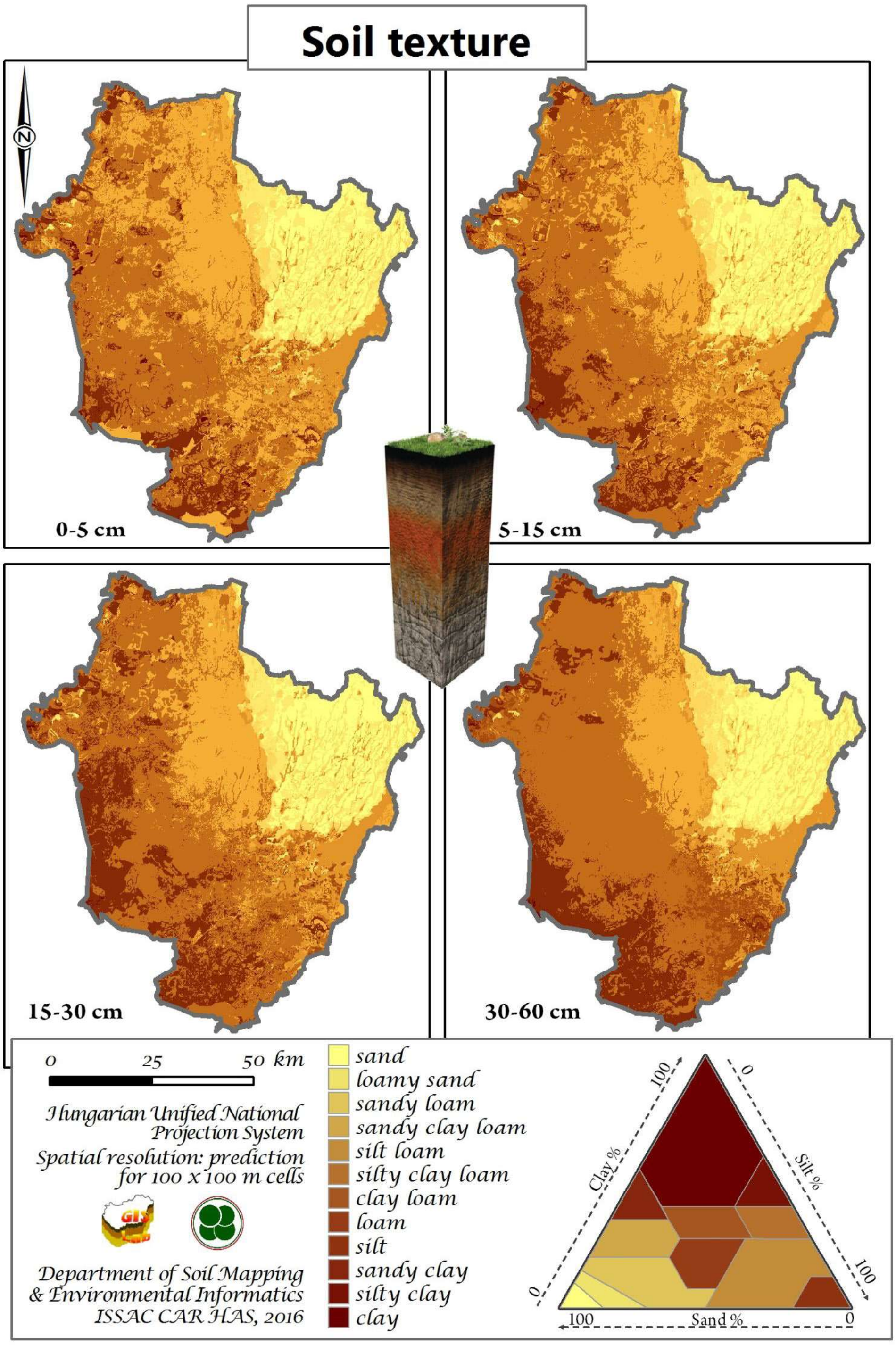

Fig 4. Soil texture maps by standard layers according to the USDA classification system

specifications – Arrouays 2014) by equal-area spline interpolation (Bishop et al. 1999; Malone et al. 2009; R Core Team 2015). The nationwide map creation workflow (Fig. 3) for the topsoil layer (0-5 cm) is presented in details in recent papers (Laborczi et al. 2016; Pásztor et al. 2016c). The deeper soil layers were also mapped with similar approach. For the support of regional studies, the countrywide maps of the four upper layers were clipped and compiled as layouts for the area of Hajdú-Bihar county (Fig. 4).

4. Soil productivity map based on spatialized, scenario driven crop modelling

Nowadays crop simulation models provide proper environment to grow plants conditioned by various environmental factors characterized by actual, predicted or presumed data. Applying rational meteorological and management scenarios, modelling yields for different crops produce multiple results, whose proper aggregation provides an appropriate approximation of land productivity. Basically, crop models work on single plots, but if all the input is available in map form, the results will be also spatialized.

Model calculations were carried out for the five most important crops, whose summarized territorial representation in the Hungarian agricultural reaches 80-85%, namely: winter wheat, barley, maize, sunflower and rapeseed. Each crop was grown for 30 years applying daily, actual as well as generated climate data. In addition to the application of various climatic data inputs, further scenarios were tested changing agro-management parameters. Water and nutrient supplies were altered in three distinct grades: optimal, normal and poor supply categories were introduced. Yields predicted along crop, water and nutrient supply scenarios resulted numerous maps modelling specific components of productivity function of soils. To produce a unique, easily communicable product we aggregated the results. Crop yields were standardized using wheat equivalent yield, then the scenario results were weighted according to their estimated representativity and then summarized. The result characterizes the land's productivity in the case of the most rational practices and most frequent environmental conditions. The nationwide map creation workflow (Fig. 5.) is presented in details in a recent paper (Pásztor et al. 2016b). The map itself is published in a properly generalized form in the new National Atlas of Hungary. For the support of regional studies, the countrywide map was clipped and compiled as layout for the area of Hajdú-Bihar county (Fig. 6.).

5. Wind erosion susceptibility map

In Hungary wind erosion causes serious problems in agricultural production as well as in soil and environmental quality (Lóki 2011; Lóki et al. 2012; Szabó – Lóki 2013; Négyesi

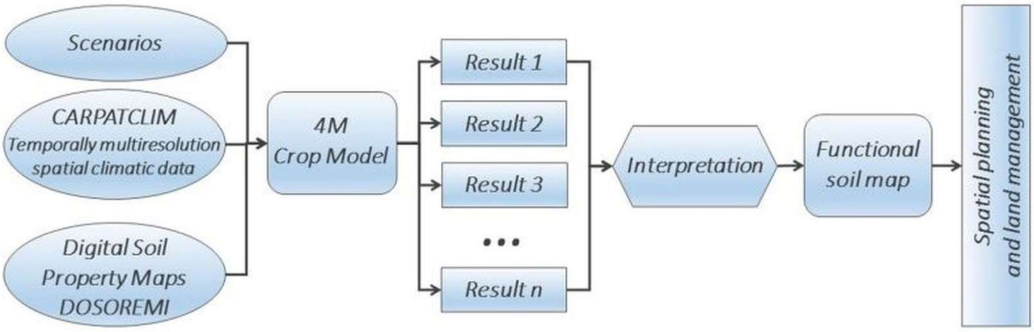

Fig. 5. Conception of mapping functional soil maps

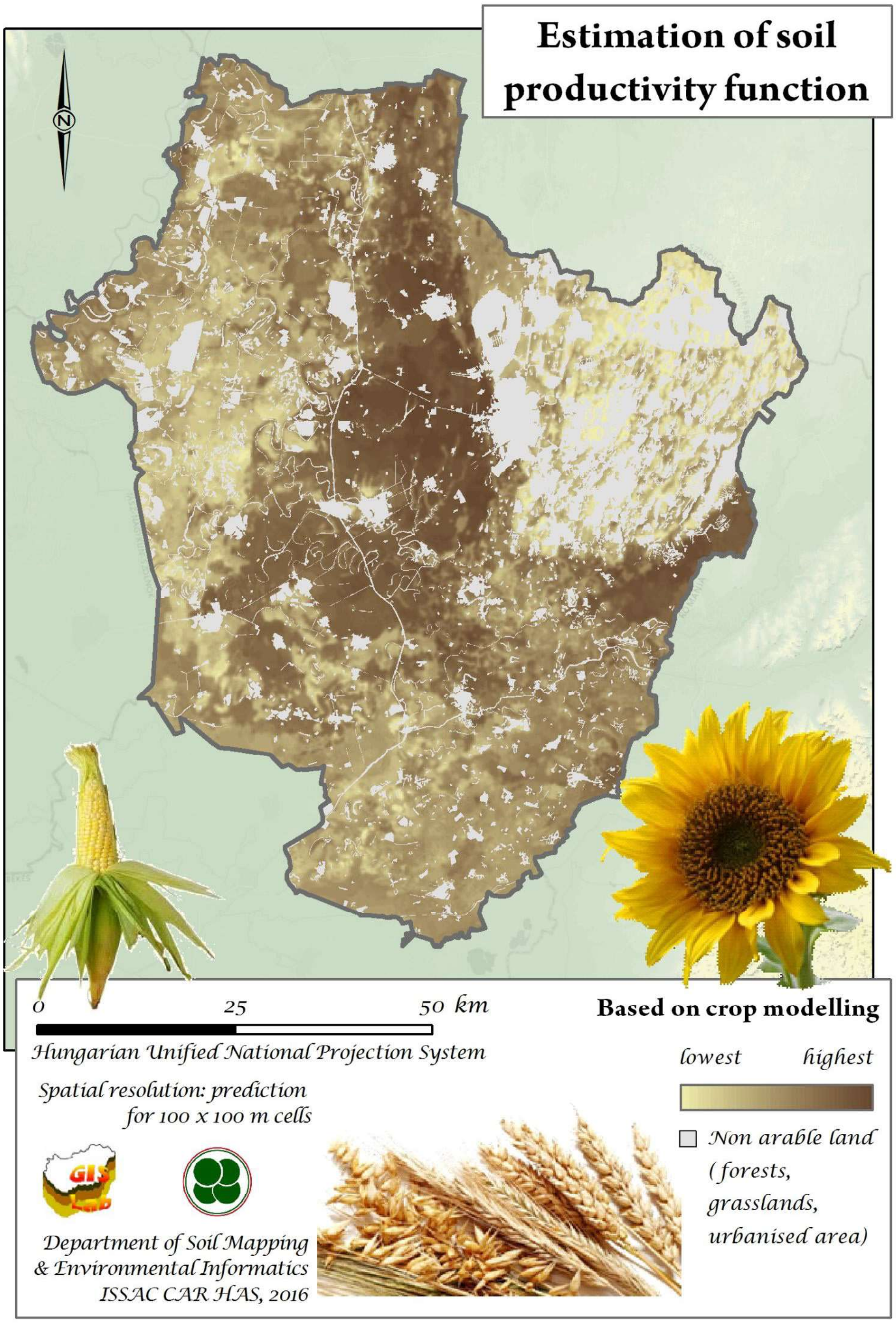

Fig. 6. Soil productivity map based on spatialized, scenarios driven crop model result

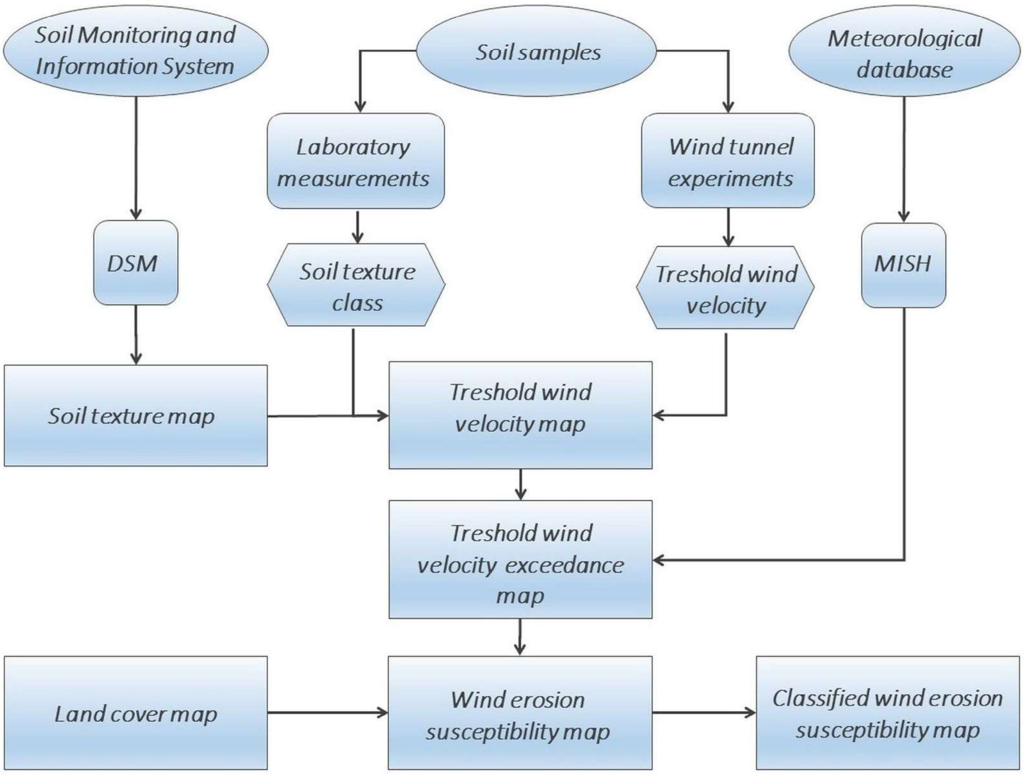

Fig. 7. Compilation process of the wind erosion susceptibility map

et al. 2015). Wind erosion susceptibility of the Hungarian soils was mapped on national level integrating three pillars of the complex phenomenon of deflation. Results of wind tunnel experiments on erodibility of various and representative soil samples were used for the parametrization of countrywide map of soil texture compiled for the upper 5 centimeter layer of soil, which resulted in a map representing threshold wind velocity exceedance. Average wind velocity was spatially estimated with 0.5' resolution using the MISH method (Szentimrey – Bihari 2007) elaborated for the spatial interpolation of surface meteorological elements. The ratio of threshold wind velocity exceedance was determined based on values predicted by the soil texture map at the grid locations. Ratio values were further interpolated to a finer 1 ha resolution using sand and silt content of the uppermost (0-5 cm) soil as spatial co-variables. Land cover (CLC50, Büttner et al. 2004) was also taken into account excluding areas which are not relevant from the aspect of wind erosion (forests, water bodies, settlements etc.) to spatially assess the risk of wind erosion. According to the resulted map of wind erosion susceptibility, about 10% of the total area of Hungary can be identified as susceptible for wind erosion, which is in good agreement with the result of former works (Lóki 2012; Mezősi et al. 2015). The map gives more detailed insight into the spatial distribution of wind-affected areas in Hungary as opposed to former works. The nationwide map creation workflow (Fig. 7.) is presented in details in a recent paper (Pásztor et al. 2016c). For the support of regional studies, the countrywide map was clipped and compiled as layout for the area of Hajdú-Bihar county (Fig. 8.).

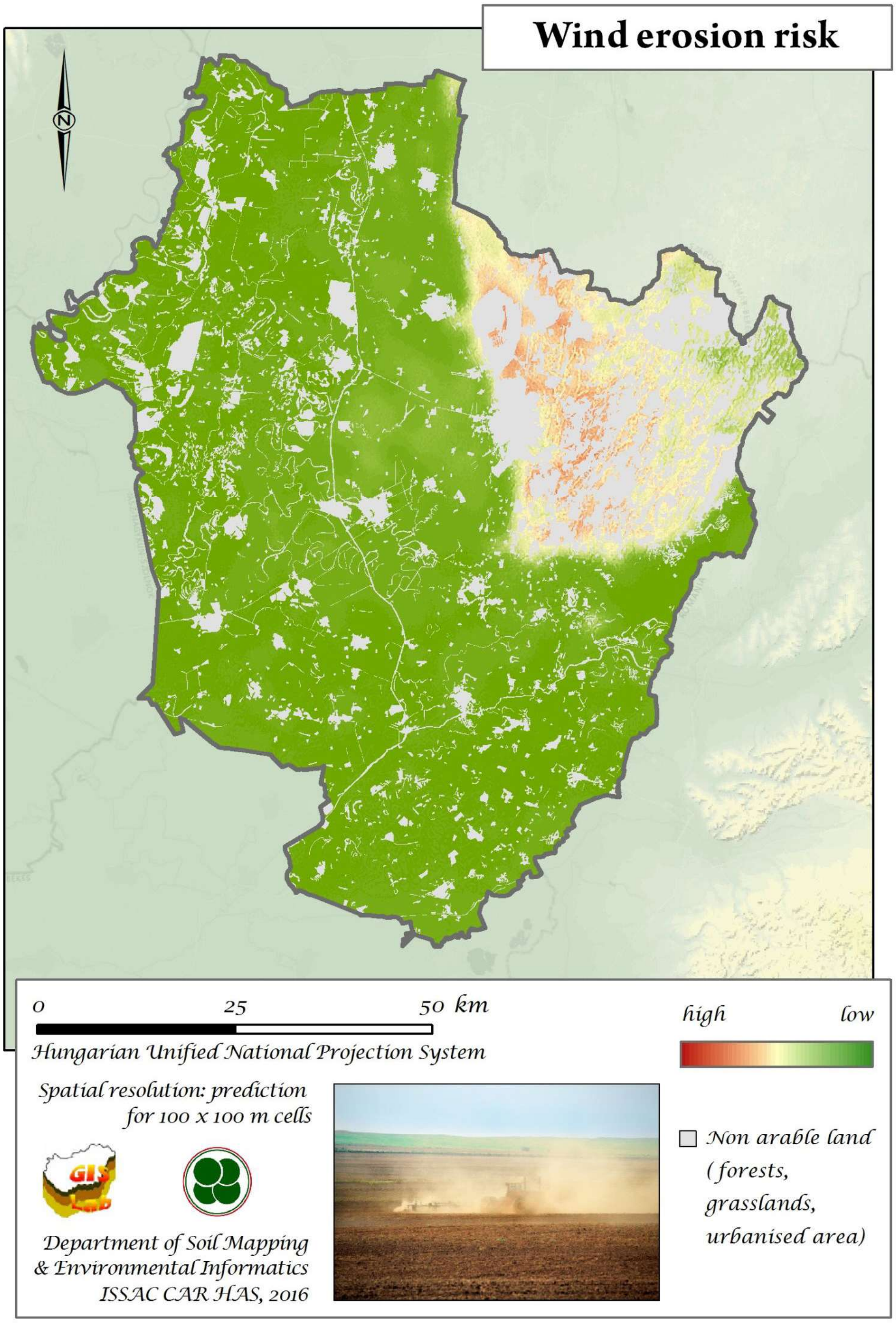

Fig. 8. Wind erosion susceptibility map

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